

Dark Matter Experiments at Fermilab

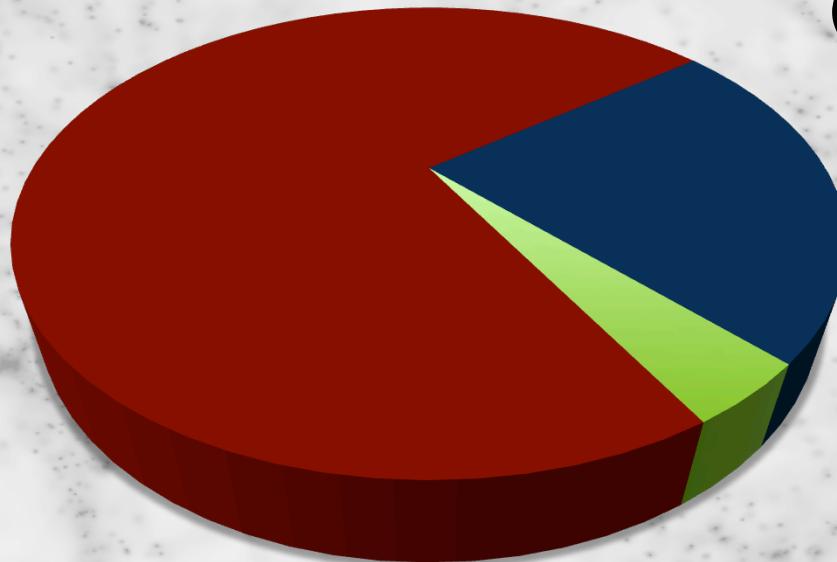
CDMS, COUPP, DarkSide

Jeter Hall

Fermilab Center for Particle Astrophysics

The Cosmic Frontier

Dark Energy
 $(p \approx \rho^{-1})$
~ 73%



- Dark Energy
 - DES/JDEM (J. Estrada)
- Dark Matter
 - CDMS/COUPP/DarkSide

Dark Matter
(Cold, Non-Baryonic)
~ 23%

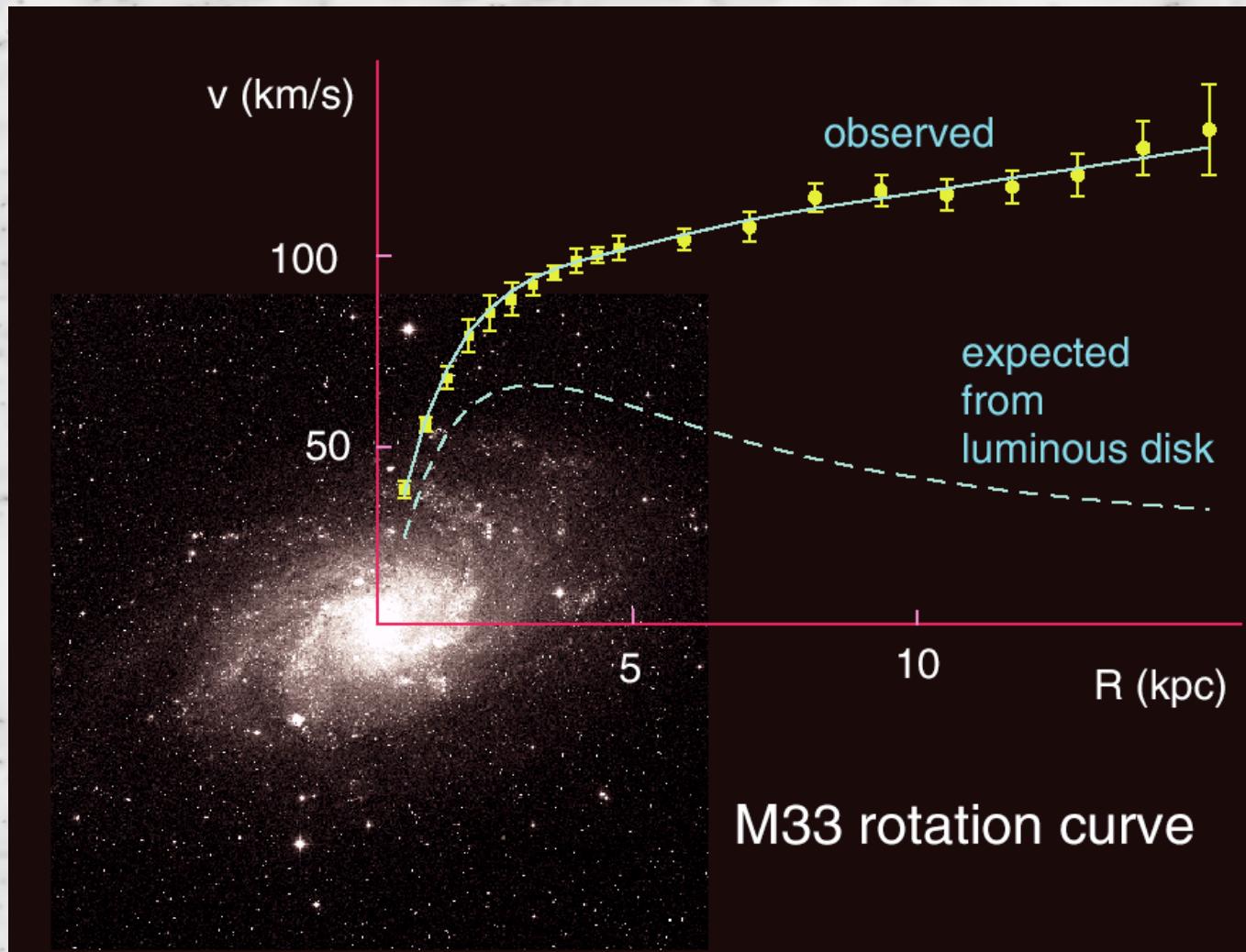
Standard Model
~ 4%

THE STANDARD MODEL									
	Fermions			Bosons			Force carriers		
	Quarks	C	T	γ	Z	W			
u	up	c	charm	t	photon				
d	down	s	strange	b	Z boson				
V _e	electron neutrino	V _μ	muon neutrino	V _τ	tau neutrino				
e	electron	μ	muon	τ	gluon				
					Higgs [*] boson				

*Yet to be confirmed

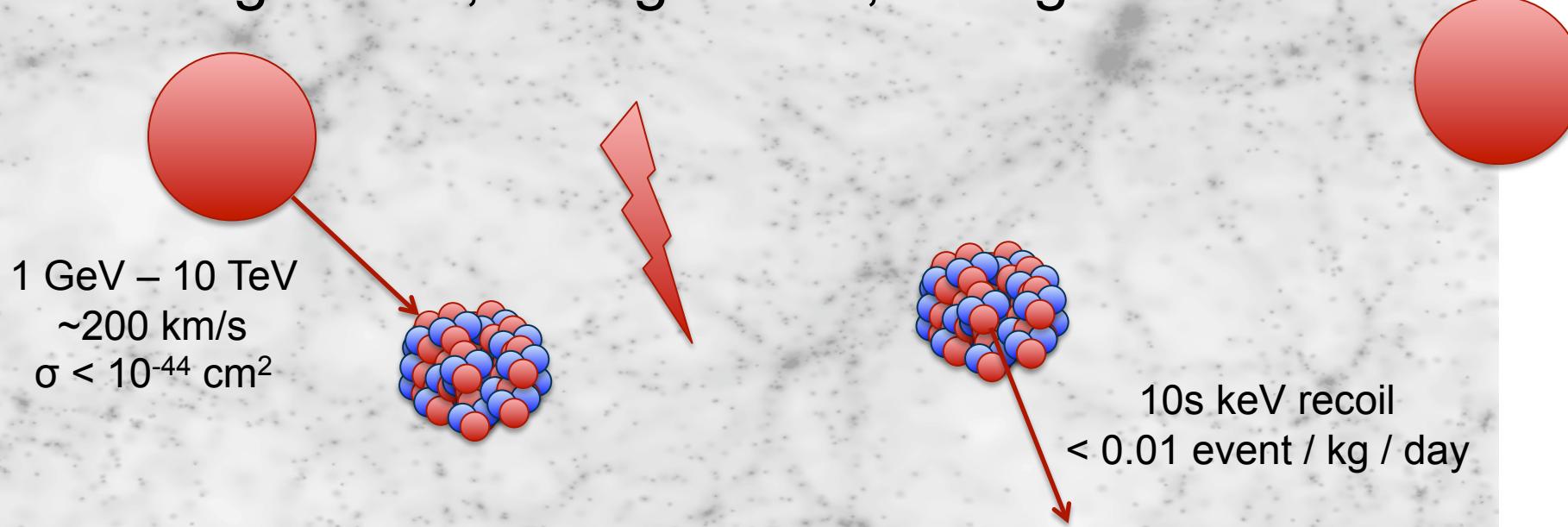
Source: AAAS

The Dark Matter Problem

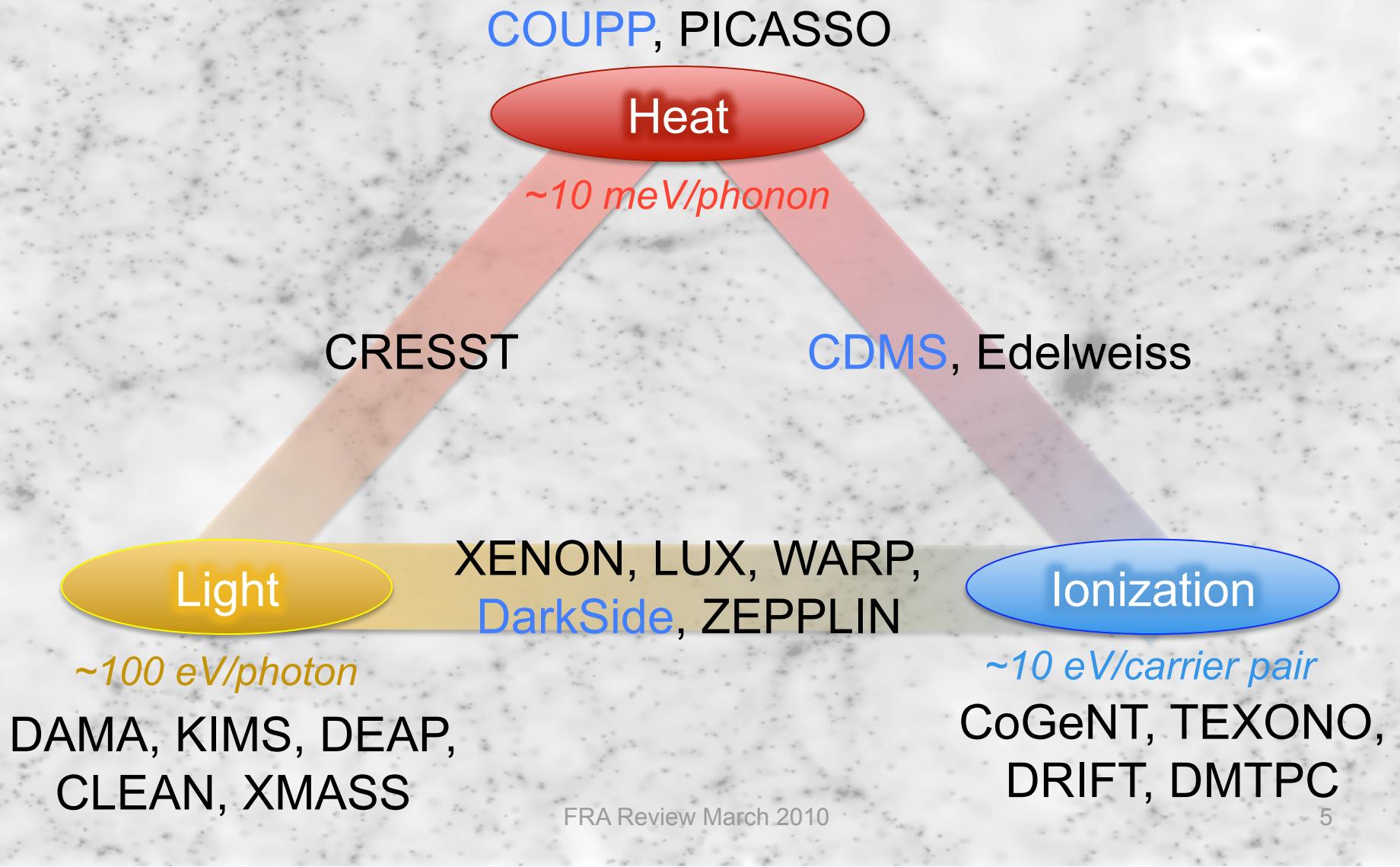


Direct Detection of Dark Matter

- Searching for WIMP-Nucleus elastic scattering
- In a sea of background radiation
 - Backgrounds, backgrounds, backgrounds...



Direct Detection Techniques



Dark Matter in PASAG

- SuperCDMS-Soudan is supported in order to prove the detector technology for SuperCDMS-SNOLAB
- The 100 kg SuperCDMS experiment in SNOLAB is specifically recommended in all budget scenarios
- The 500 kg COUPP bubble chamber construction is recommended in all budget scenarios
- An effort in depleted Argon is supported in all budget scenarios



The Cryogenic Dark Matter Search

California Institute of Technology

Z. Ahmed, J. Filippini, S.R. Golwala, D. Moore, R.W. Ogburn

Case Western Reserve University

D. Akerib, C.N. Bailey, M.R. Dragowsky,
D.R. Grant, R. Hennings-Yeomans

Fermi National Accelerator Laboratory

D. A. Bauer, F. DeJongh, J. Hall, D. Holmgren,
L. Hsu, E. Ramberg, R.L. Schmitt, J. Yoo

Massachusetts Institute of Technology

E. Figueroa-Feliciano, S. Hertel,
S.W. Leman, K.A. McCarthy, P. Wikus

NIST *

K. Irwin

Queen's University

P. Di Stefano *, N. Fatemighomi *, J. Fox *,
S. Liu *, P. Nadeau *, W. Rau

Santa Clara University

B. A. Young

Southern Methodist University

J. Cooley

SLAC/KIPAC *

E. do Couto e Silva, G.G. Godfrey, J. Hasi,
C. J. Kenney, P. C. Kim, R. Resch, J.G. Weisend

Stanford University

P.L. Brink, B. Cabrera, M. Cherry *,
L. Novak, M. Pyle, A. Tomada, S. Yellin

Syracuse University

M. Kos, M. Kiveni, R. W. Schnee

Texas A&M

J. Erikson *, R. Mahapatra, M. Platt *

University of California, Berkeley

M. Daal, N. Mirabolfathi, A. Phipps, B. Sadoulet,
D. Seitz, B. Serfass, K.M. Sundqvist

University of California, Santa Barbara

R. Bunker, D.O. Caldwell, H. Nelson, J. Sander

University of Colorado Denver

B.A. Hines, M.E. Huber

University of Florida

T. Saab, D. Balakishiyeva, B. Welliver *

University of Minnesota

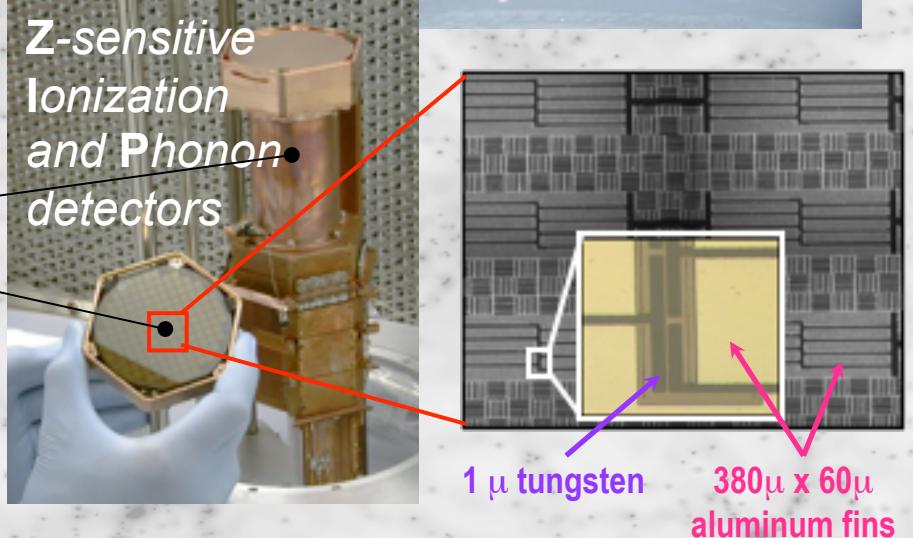
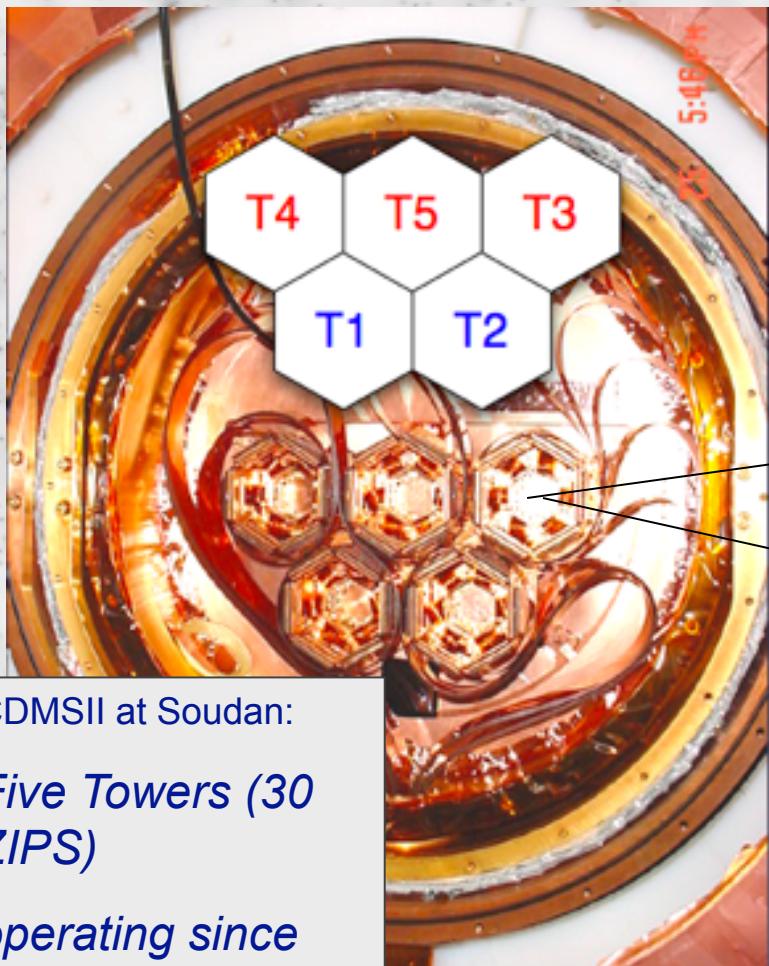
J. Beaty, P. Cushman, S. Fallows, M. Fritts,
O. Kamaev, V. Mandic, X. Qiu, A. Reisetter, J. Zhang

University of Zurich

S. Arrenberg, T. Bruch, L. Baudis, M. Tarka

* new collaborators or new institutions in SuperCDMS

The CDMS Experiment

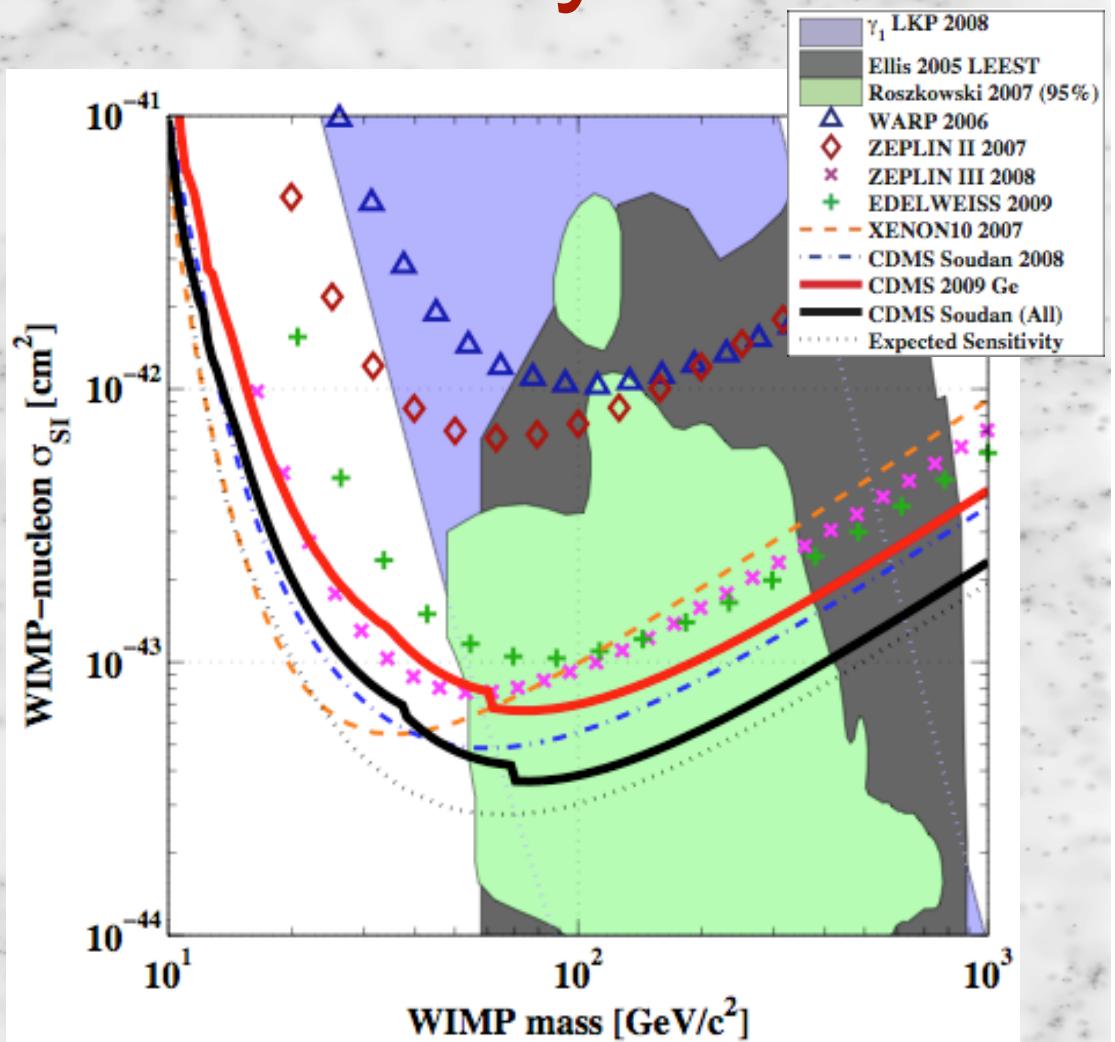


Fermilab CDMS Group

- Leadership roles in
 - Cryogenics (D. Bauer, R. Schmitt, T. Tope)
 - Analysis (J. Hall, D. Holmgren, L. Hsu, J. Yoo)
 - Operations (D. Bauer)
 - Electronics (F. DeJongh, J. Hall, S. Hansen)

CDMS Sensitivity

- 2 events with an exposure of 200 kg days
- Low expected background of 0.9 events
- Leading the world in sensitivity to spin-independent WIMP-nucleus elastic scattering

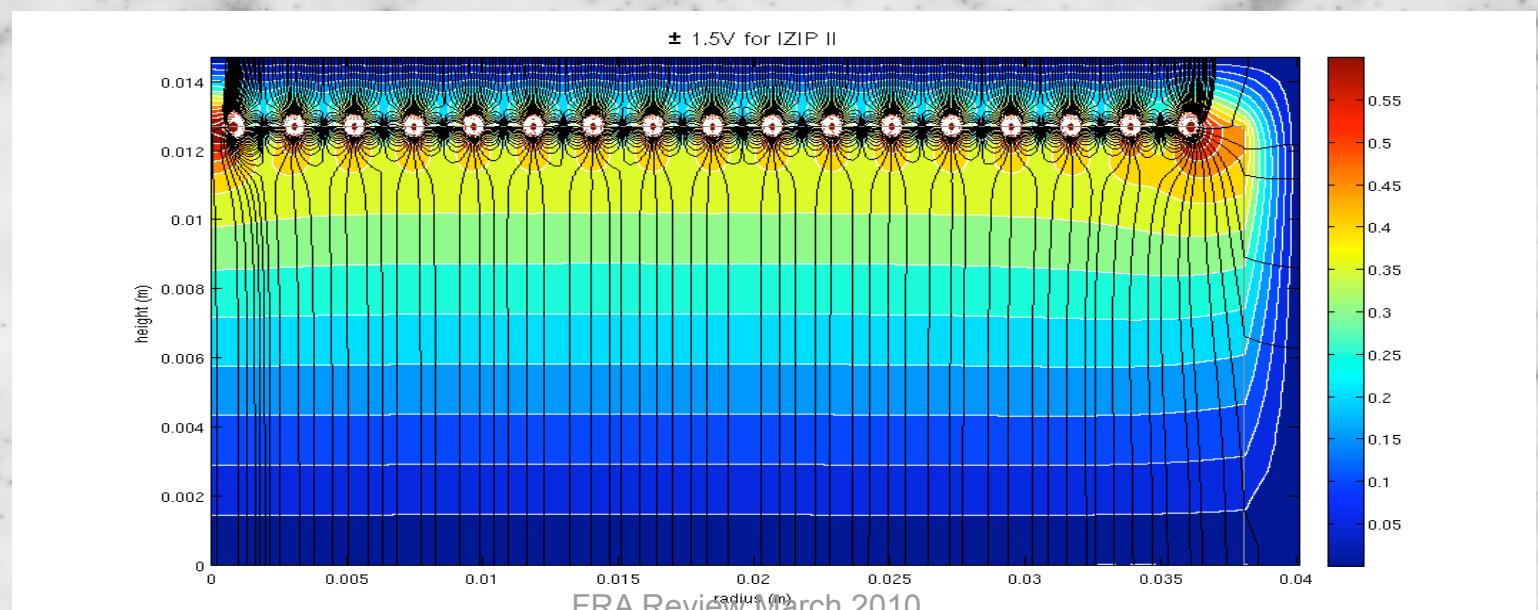


Recent CDMS Results

- Dark Matter Search Results from the CDMS II Experiment
 - *Science* 10.1126/science.1186112 (2010)
- Analysis of the Low-Energy Electron-Recoil Spectrum of the CDMS Experiment
 - *Physical Review D* **81**, 042002 (2010)
- Search for Axions with the CDMS Experiment
 - *Physical Review Letters* **103**, 141802 (2009)
- Search for Weakly Interacting Massive Particles with the First Five-Tower Data from the Cryogenic Dark Matter Search at the Soudan Underground Laboratory
 - *Physical Review Letters* **102**, 011301 (2009)

CDMS Technology Breakthrough

- New symmetric detectors (iZIP) have demonstrated a background rejection improvement of more than an order of magnitude (ton scale CDMS style experiment now feasible)
- First production of iZIPs now ongoing
- Trial run this summer in Soudan facility





COUPP



**Kavli Institute
for Cosmological Physics**
AT THE UNIVERSITY OF CHICAGO

University of Chicago

J. Collar, C.E. Dahl, D. Fustin, M. Szydagis

Indiana University South Bend

**E. Behnke, J. Behnke, J.H. Hinnefeld, I. Levine, A.
Palenchar, T. Shepard, B. Sweeney**

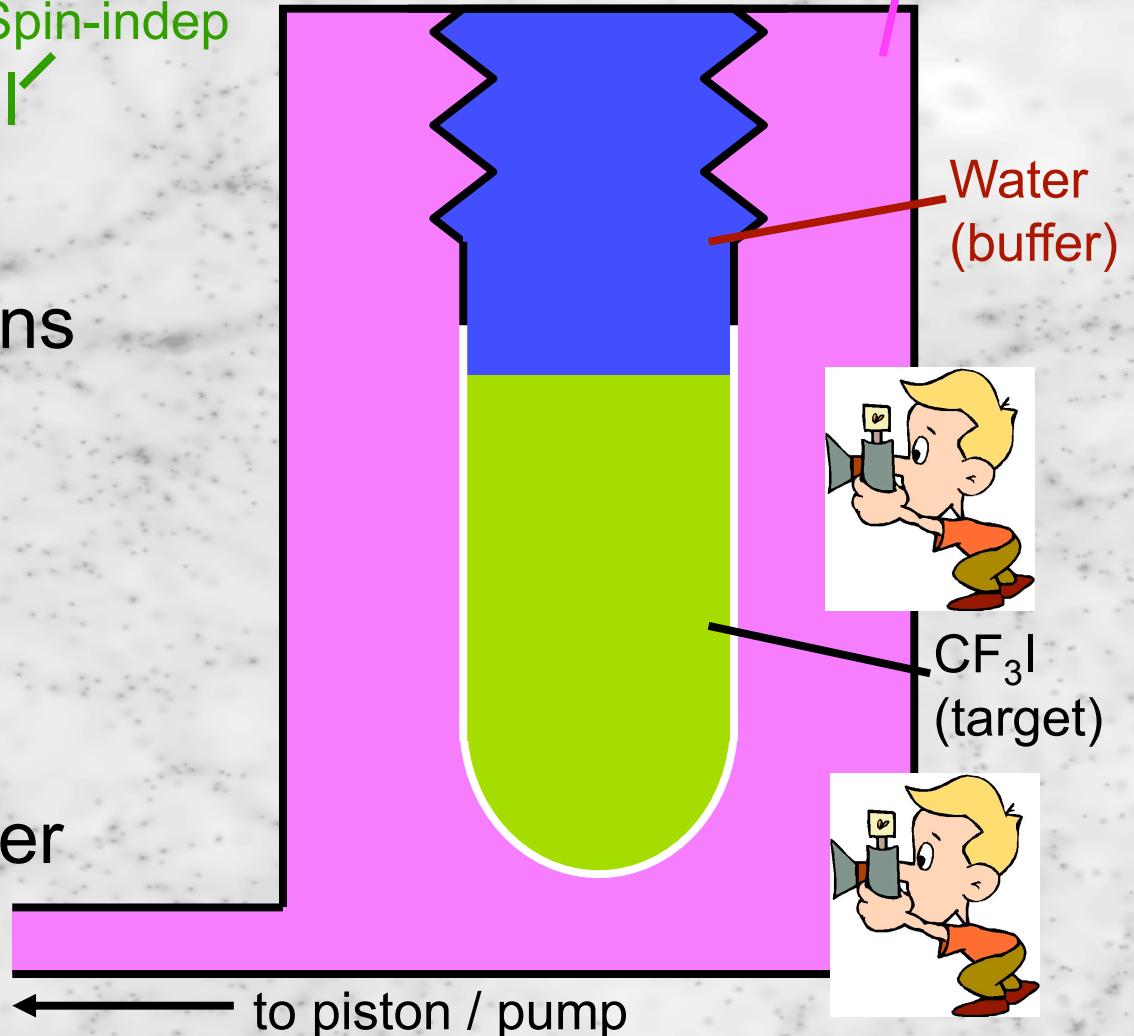


Fermi National Accelerator Laboratory

**S. Brice, D. Broemmelsiek, P. Cooper, M. Crisler,
J. Hall, M. Hu, E. Ramberg, A. Sonnenschein**

COUPP Technique

- Superheated CF_3I target
 - Spin-indep
 - Spin-dep



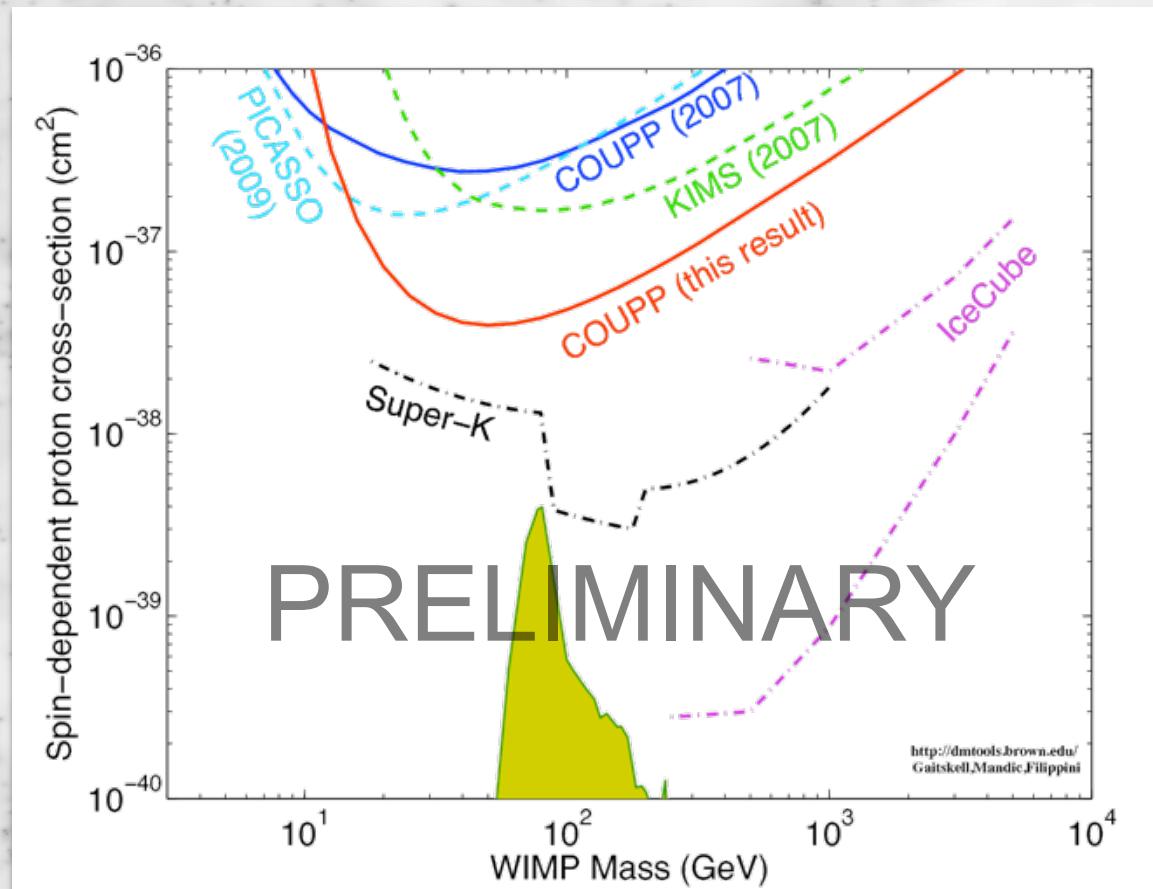
- Particle interactions nucleate bubbles
- Cameras capture bubbles
- Chamber recompresses after each event

Fermilab Role in COUPP

- Operations (A. Sonnenschein)
- MINOS Near Hall Logistics (E. Ramberg)
- Analysis (S. Brice, J. Hall)
- DAQ (D. Broemmelsiek, P. Cooper)
- R&D (M. Crisler)

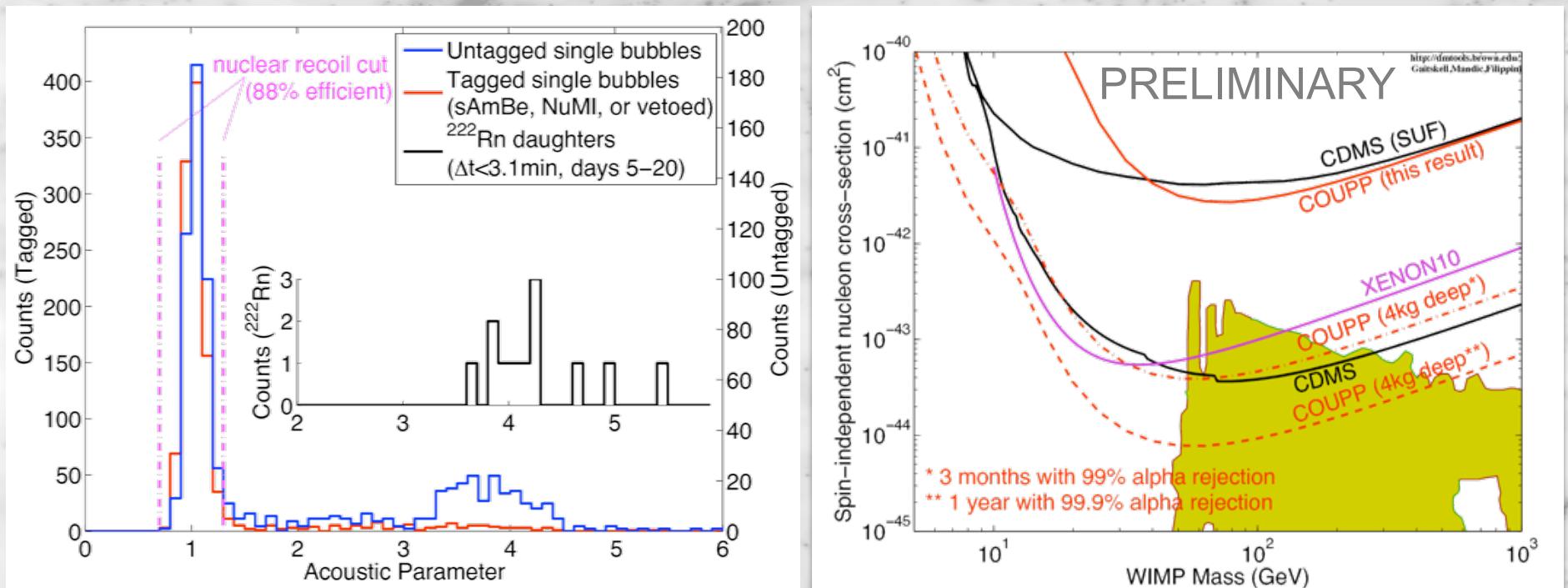
COUPP Results

- Blue line –
Science
319:933-936 (2008)
- Red line –
latest result see the
Joint Experimental-
Theoretical Seminar
today at 4 pm
- Latest results limited
by cosmic radiation
in the MINOS near
hall



COUPP Technological Advance

- Hints that new ultrasound transducers reduce the backgrounds by 2-3 orders of magnitude



COUPP Program

- Implementing a rapid scaling of detector mass
- As smaller detectors are run to develop an understanding of backgrounds
- A 60 kg dark matter bubble chamber has been constructed and is ready for deployment in the MINOS near hall to develop robust remote operations
- A 500 kg chamber is under discussion



DarkSide and MAX

DarkSide Collaboration : UMass Amherst, Arizona State, Augustana College, Black Hills State, Fermilab, Houston, Notre Dame, Princeton, Temple, UCLA

- **DarkSide-50 (50 kg, 10^{-45} cm 2)**

DarkSide + XENON = MAX Collaboration

UMass Amherst, Arizona State, Augustana, Black Hills State, Coimbra, Columbia University, Fermilab, Houston, INAF, LNGS, MIT, Münster, Notre Dame, Princeton, Rice, Shanghai Jiao Tong, Temple, UCLA, Virginia, Waseda, Zürich

- **5t Depleted Argon and 2.5t Xe TPCs (10^{-47} cm 2)**
- **S4 Funded Project**
- **Possible change in baseline (25t DAr, 10t Xe) if DUSEL delay to 2016-2017 confirmed**

Why depleted argon?

- Atmospheric argon has specific activity 1 Bq/kg ($^{39}\text{Ar}/\text{Ar}$ ratio 8×10^{-16})

Limits size (and sensitivity) of detectors using atmospheric Argon to 500-1000 kg due to ^{39}Ar events pile-up

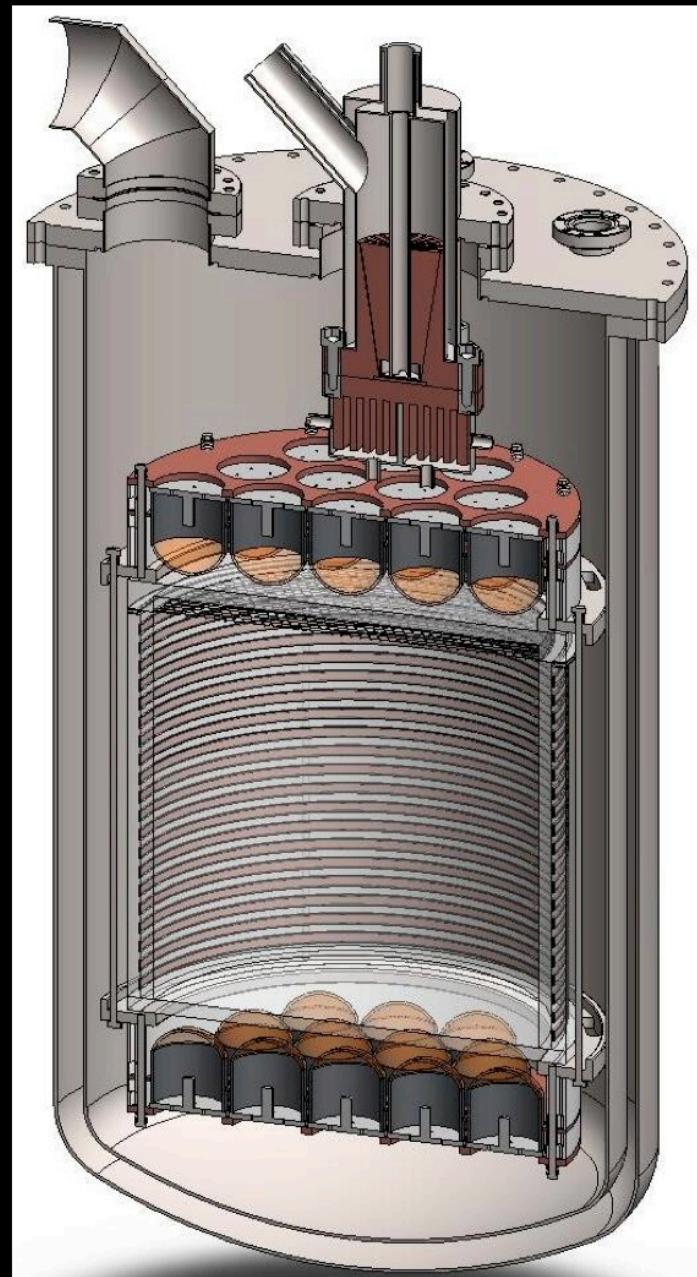
- ^{39}Ar produced by cosmic rays in atmosphere (beta decays, $Q = 565 \text{ keV}$, $t_{1/2} = 269 \text{ years}$)
- ^{39}Ar -depleted argon available via centrifugation or thermal diffusion, but expensive at the ton scale!
- ^{39}Ar production by cosmic rays strongly suppressed underground

DarkSide-50

dual-phase TPC
50 kg active mass
background-free for 3 yrs
sensitivity 10^{-45} cm^2

**Test for three advances crucial
to achieve zero background:**

- 1) depleted argon
- 2) QUPIDs at LAr temp
- 3) active liquid scintillator
neutron veto



adapted from C.Galbiati PAC presentation 11/09

Fermilab Responsibilities

- DarkSide-50:
 - Cryogenic Simulations
 - DAQ and Electronics (w Houston)
 - Purification (w Temple)
 - Shielding and Muon Veto
- MAX:
 - See WBS of MAX S4 proposal

Conclusions

- Fermilab is the leading national laboratory in the dark matter efforts of the Cosmic Frontier
 - CDMS is leading the field in spin-independent dark matter scattering sensitivity
 - COUPP is leading the field in spin-dependent dark matter scattering sensitivity
 - DarkSide and the development of depleted Argon have the potential of changing the direction of the field